Artificial Intelligence Research in India: A Scientometric Assessment of Publications Output during 2007-16

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ABSTRACT

The paper examines the world output in artificial intelligence research, a total of 1,52,655 publications, as seen from Scopus database, covering the period during 2007-16. The top 10 countries of the world in artificial intelligence research accounted for 74.32 per cent global publication share. Individually their global share varied from 3.68 per cent to 19.46 per cent, with China accounting for 19.46 per cent global share, followed by the USA (17.96 %), India (6.37 %), and the U.K. (6.33 %), etc. The paper also examines publications output by India in artificial intelligence research. India cumulated a total of 9730 publications in 10 years during 2007-16, registered an annual average growth rate of 27.45 per cent, averaged citation impact to 2.76 citations per paper, and contributed 10.34 per cent share of its total country output as international collaborative publications during 2007-16. Computer science accounted for the largest publication share (86.99 %), followed by engineering (30.69 %), mathematics (15.95 %), biochemistry, genetics & molecular biology (4.66 %), and several other disciplines. The top 10 organizations and 10 authors together accounted for 19.31 per cent and 2.71 per cent national publications share respectively and 29.78 per cent share and 6.85 per cent national citation share respectively during 2007-16. Top 10 journals accounted for 15.45 per cent share of the country output appearing in journal medium (1650 papers). India accounted for 24 highly cited papers, averaging to 162.46 citations per paper. These 24 highly cited papers involved the participation of 109 authors from 70 organizations, published in 15 journals.

Keywords: Artificial intelligence; India; Publications; Highly cited papers; Scientometrics; Bibliometrics

1. INTRODUCTION

According to the father of artificial intelligence (AI), John McCarthy, artificial intelligence is defined as the "The science and engineering of making intelligent machines, especially intelligent computer programs". Artificial intelligence is a way of making a computer, computer-controlled software thinks intelligently, in a manner similar to the way intelligent humans think. The main goals of AI are: (i) to create expert systems - the systems which exhibit intelligent behavior, learn, demonstrate, explain and advice its users and (ii) to implement human intelligence in machines – to create systems that understand, think, learn and behave like humans. Artificial intelligence is about select science and technology based on disciplines such as computer science, biology, psychology, linguistics, mathematics and engineering. A major thrust of AI is in development of computer functions associated with human intelligence such as reasoning, learning and problem solving. AI has been dominant in various fields such as gaming, natural language processing, expert systems, vision systems, speech recognition, handwriting recognition and intelligent robots. The domain of AI is huge in breadth and width. Here we consider common and prospering research areas in the domain of AI as: expert systems, natural language processing, neural networks, fuzzy logic and robotics[1].

1.1 Literature Review

A select few studies that were undertaken in the past focused on quantitative analysis of global output on artificial intelligence research covering different study periods and different aspects of the subject in their research analysis.. Among such studies, Niu[2], *et al.* (i) carried out a multi-angle assessment of research productivity in the area of artificial research (AI) by subject category, journal, author, country, institution and keywords covering the period during 1990 to 2014; (ii) analyzed significant publication patterns in the domain of AI research; and (iii) provided a summarization of the research directions and trends in the field of AI. Gunasekaran and Shanmugam[3] examined global artificial intelligence research output (10795 papers) published during 1981-2010, and reported growth characteristics, continent-wise and country-wise distribution, identification of prolific authors and journals, collaborative patterns, etc. Cheng and Wang[4] analyzed global artificial intelligence research output covering the period during 2000-2011, and reported article distribution by publication year, languages, countries/regions, authors,

journals, etc. Besselaar and Leyesdorf[5] mapped changes in development of artificial intelligence specialty during 1982-1992. The authors used aggregated journal-to-journal citations for describing AI as sets of journals; they used factor analytical technique to analyze the developments in AI in terms of (emerging) stability and coherence of the journal sets during the period 1982 to 1992. Shrivastava and Mahajan[6] studied the artificial intelligence research in Indian context which analysed data from Scopus database published during 1968 to 2014. The study reported growth characteristics, citation per paper, keywords, national and international collaboration, and organization-wise distributions, etc. Besides, there were a few other bibliometric studies carried out in India, which assessed the overall computer science research output (including artificial intelligence) in India and covered different study aspects and periods[7-10].

2. OBJECTIVES

The main aim of this study is to understand India's performance in artificial intelligence research covering research data published during 2007-16. The publications data for the study was sourced from Scopus database. In particular, the study focuses on the following objectives

- To study the global output in artificial intelligence research and contribution of top 10 most productive countries
- To study the growth of Indian research output in artificial intelligence, its global share and its citation impact
- To study the international collaboration of Indian publications and contribution of most significant partner countries
- To study the Indian research output by broad subject areas and the dynamics of its growth and decline
- To study the trends in Indian research by identifying significant keywords
- To study the publication productivity and citation impact of top 10 most productive Indian organizations and authors
- To study the modes of communication in research
- To study the characteristics of top highly cited papers.

3. METHODOLOGY

The study retrieved and downloaded 10-year publications data of the world in artificial intelligence research from the Scopus database (http://www.scopus.com) covering the period 2007-16. Keywords such as "artificial intelligence" were tagged to "Keyword tag" and "Article tag", and the search period '2007-16' to "date range tag". This search strategy was used as the main search string to get publications data of the world output and also publications data of top 10 most productive countries. This main search string was further restricted to India in "Affiliation tag" to get publication data on India's output on artificial intelligence research. By applying analytical provisions/ tags available in Scopus database such as "subject area tag", "country tag", "source title tag", "journal title name" and "affiliation tag" – India's output was accordingly refined by subject, collaborating countries, organization-wise, author-wise and journal-wise, etc. For citation data, citations to publications were also collected from date of publication till 15

May 2017. The Indian publications data was analyzed across a few select bibliometric indicators with a view to understand the research activity in artificial intelligence research. We have used here complete counting method, where all authors or organizations to multi-authored papers have received equal credit in data counting and analysis. All types of documents have been used in this study. The conference papers and papers in book series and journals together constitute 99.86 % of the total Indian publications output in artificial intelligence during 2007-16. For impact factor, 2015 data has been used and is collected from the journal websites.

(KEY (artificial intelligence) OR TITLE (artificial intelligence)) AND PUBYEAR > 2006 AND PUBYEAR < 2017

(KEY (artificial intelligence) OR TITLE (artificial intelligence)) AND PUBYEAR > 2006 AND PUBYEAR < 2017 AND (LIMIT-TO (AFFILCOUNTRY, "India"))

4. ANALYSIS

The global research output in field of artificial intelligence cumulated to a total of 152655 publications in 10 years during 2007-16. The world output grew by 9.82 per cent per annum, and the annual world output increased in volume from 9770 in 2007 to 21417 publications in 2016. Five-year research output of the world in artificial intelligence jumped by 48.95 per cent from 61320 in 2006-11 to 91335 publications in 2012-16. The growth in the latter half of the study period 2012-16 was relatively faster.

India's research output in field of artificial intelligence cumulated to a total of 9730 publications in 10 years during 2007-16. India registered 27.45 per cent growth per annum, and its annual output increased in volume from 290 in 2007 to 2221 publications in 2016. Five-year research output of the country jumped by 209.17 per cent, from 2378 in 2006-11 to 7352 publications in 2012-16.

India's global share in artificial intelligence research was 6.37 per cent during 2007-16; its five-year global share increased substantially from 3.88 per cent in 2007-11 to 8.05 per cent in 2012-16. The citation impact of India's publications output in artificial intelligence research averaged to 2.76 citations per paper in 10 years during 2007-16. Its five-year citation impact declined from 6.30 in 2007-11 to 1.61 CPP in 2012-16 as shown in Table 1.

4.1 International Collaboration

India's share of internationally collaborative papers (ICP) in its total output in artificial intelligence research was 10.34 per cent during 2007-16, which registered decline from 10.98 per cent in 2007-11 to 10.13 per cent in 2012-16. Among the leading countries that collaborated with India, USA topped the list accounting for 37.18 per cent share, followed by U.K. (10.83 %), Singapore (8.35 %), France and Canada (6.26 % and 6.06 %), Australia, Germany and Poland (from 5.27 % to 5.37 %), Italy and Malaysia (3.48 % each) during 2007-16. The top countries whose share in India's international collaborative publications increased were Poland, U.K., Malaysia, USA, Germany and Australia, whereas it decreased in the collaborative output by Canada, Singapore, Italy and

Table 1. World Output and India's Output in Artificial Intelligence Research, 2007-16

| Period | World | India | | | | | |
	TP	TP	TC	CPP	%TP	ICP	% ICP
2007	9770	290	3138	10.82	2.97	39	13.45
2008	13123	263	2562	9.74	2.00	38	14.45
2009	11823	373	2880	7.72	3.15	46	12.33
2010	12402	616	2871	4.66	4.97	65	10.55
2011	14202	836	3541	4.24	5.89	73	8.73
2012	16013	863	2895	3.35	5.39	100	11.59
2013	15212	975	2925	3.00	6.41	133	13.64
2014	17929	1319	2801	2.12	7.36	127	9.63
2015	20764	1974	2536	1.28	9.51	192	9.73
2016	21417	2221	685	0.31	10.37	193	8.69
2007-11	61320	2378	14992	6.30	3.88	261	10.98
2012-16	91335	7352	11842	1.61	8.05	745	10.13
2007-16	152655	9730	26834	2.76	6.37	1006	10.34

TP=Total Papers; TC=Total Citations; CPP=Citations Per Paper

Table 2. Leading countries accounting for their share in india's internationally collaborative research output in artificial intelligence during 2007-16

| Collaborative country | Number of collaborative papers | | | Share of collaborative papers | | |
	2007-11	2012-16	2007-16	2007-11	2012-16	2007-16
USA	96	278	374	36.78	37.32	37.18
U.K.	24	85	109	9.20	11.41	10.83
Singapore	23	61	84	8.81	8.19	8.35
France	17	46	63	6.51	6.17	6.26
Canada	23	38	61	8.81	5.10	6.06
Australia	14	40	54	5.36	5.37	5.37
Germany	13	40	53	4.98	5.37	5.27
Poland	5	48	53	1.92	6.44	5.27
Italy	10	25	35	3.83	3.36	3.48
Malaysia	5	30	35	1.92	4.03	3.48
Indian Total	261	745	1006	100.00	100.00	100.00

Table 3. Global Publication Share of Top 10 Most Productive Countries in Artificial Intelligence Research during 2007-16

| Name of the Country | Number of Papers | | | Share of Papers | | |
	2007-11	2012-16	2007-16	2007-11	2012-16	2007-16
China	14607	15095	29702	23.82	16.53	19.46
USA	10706	16705	27411	17.46	18.29	17.96
India	2378	7352	9730	3.88	8.05	6.37
U.K.	3593	6068	9661	5.86	6.64	6.33
Germany	2839	5359	8198	4.63	5.87	5.37
Spain	2779	4278	7057	4.53	4.68	4.62
France	2284	4425	6709	3.72	4.84	4.39
Italy	1975	3886	5861	3.22	4.25	3.84
Japan	2041	3587	5628	3.33	3.93	3.69
Canada	2372	3251	5623	3.87	3.56	3.68
Total	45574	70006	115580	74.32	76.65	75.71
World	61320	91335	152655	100.0	100.0	100.0
Share of 10 Countries in World Total	74.32	76.65	75.71			

France during 2007-11 to 2012-16 as shown in Table 2.

4.2. Top 10 Most Productive Countries in Artificial Intelligence Research

Artificial intelligence research is spread across more than 100 countries as seen from publications data during 2007-16. Top 10 most productive countries accounted for 75.71 per cent global publication share in artificial intelligence research in 10 years. Their cumulated research output ranged between 5623 and 29702 publications and their global publications share ranged between 3.68 per cent and 19.46 per cent during 2007-16. Their five-year global publication share increased marginally from 74.32 per cent in 2007-11 to 76.65 per cent in 2012-16. China accounted for the largest global publication share (19.46 %) in 10 years, followed by USA (17.96 %), India and U.K. (6.37 % and 6.33 %), Germany (5.37 %), Spain and France (4.62 % and 4.39 %), Italy, Japan and Canada (from 3.68 % to 3.84 %) during 2007-16. India's five year research output increased by 4.17 per cent, followed by 1.24 per cent in Germany, 1.12 per cent in France, 1.03 per cent in Italy, 0.83 per cent in USA, 0.78 per cent in U.K., 0.60 per cent in Japan and 0.15 per cent in Spain, whereas it decreased by 7.29 per cent in China and 0.31 per cent in Canada from 2007-11 to 2012-16 as shown in Table 3.

4.3 Subject-Wise Distribution of Research Output

The artificial intelligence research output by India published during 2007-16 is distributed across eight sub-fields (as identified in Scopus database classification), with computer science accounting for the highest publications share (86.99 %), followed by engineering (30.69 %), mathematics (15.95 %), biochemistry, genetics & molecular biology (4.66 %), energy (3.96 %), decision science (3.45 %), social sciences (3.02 %) and medicine (2.26 %) during 2007-16. The activity index, which computes change in research activity in a discipline over time 2007-11 to 2012-16 (world average activity index of a given subject is taken as 100), witnessed increase in computer science (from 99.97 to 100.01), engineering (from 74.13 to 108.37), mathematics (from 80.15 to 106.42), biochemistry, genetics & molecular biology (from 62.32 to 112.19), energy (from 47.82 to 116.88) and decision science (from 42.62 to 118.56), whereas activity index declined in social sciences (from 162.83 to 79.68) and medicine (from 128.33 to 90.84) from 2007-11 to 2012-16. Medicine, among subjects, registered the highest citation impact per paper (13.30), followed by biochemistry, genetics & molecular biology (6.40), energy (4.40), mathematics (3.84), decision science (3.08), engineering (2.90), social sciences (2.37) and computer science (2.27) during 2007-16 as shown in Table 4.

Table 4. Subject wise breakup of publications output of india in artificial research during 2007-16

Subject*	Number of papers (TP)			Activity index		TC	CPP	%TP
	2007-11	2012-16	2007-16	2007-11	2012-16	2007-16	2007-16	2007-16
Computer science	2068	6396	8464	99.97	100.01	19220	2.27	86.99
Engineering	541	2445	2986	74.13	108.37	8652	2.90	30.69
Mathematics	304	1248	1552	80.15	106.42	5955	3.84	15.95
Biochemistry, genetics and molecular biology	69	384	453	62.32	112.19	2901	6.40	4.66
Energy	45	340	385	47.82	116.88	1693	4.40	3.96
Decision science	35	301	336	42.62	118.56	1035	3.08	3.45
Social sciences	117	177	294	162.83	79.68	698	2.37	3.02
Medicine	69	151	220	128.33	90.84	2926	13.30	2.26
Total Indian Output	2378	7352	9730					

* There is overlapping of literature covered under various subjects, TP=Total Papers; TC=Total Citations; CPP=Citations Per Paper

Table 5. Scientometric profile of top 10 most productive organizations in artificial intelligence research in india during 2007-16

Organizations	TP	TC	CPP	HI	ICP	%ICP	RCI
Anna University, Chennai	294	761	2.59	13	6	2.04	0.94
Jadavpur University, Kolkata	270	1230	4.56	17	80	29.63	1.65
Indian Institute of Technology (IIT), Delhi	206	1511	7.33	16	39	18.93	2.66
Indian Institute of Technology (IIT), Kharagpur	192	939	4.89	16	35	18.23	1.77
Indian Statistical Institute (ISI), Kolkata	177	1084	6.12	16	47	26.55	2.22
Vellore Institute of Technology (VIT), Vellore	171	452	2.64	10	18	10.53	0.96
Indian Institute of Science (IISc), Bangalore	158	698	4.42	15	39	24.68	1.60
Amrita Vishwa Vidyapeetham University, Coimbatore	157	136	0.87	6	2	1.27	0.31
Indian Institute of Technology (IIT), Madras	134	545	4.07	11	37	27.61	1.47
Indian Institute of Technology (IIT), Bombay	120	636	5.30	10	27	22.50	1.92
Total of 10 organizations	1879	7992	4.25	130	330	17.56	1.54
Total of India	9730	26834	2.76				
Share of top 10 organizations in India total output	19.31	29.78					

TP=Total Papers; TC=Total Citations; CPP=Citations Per Paper; HI=h-index; ICP=International Collaborative Papers; RCI=Relative Citation Index

Table 6. Scientometric profile of top 10 most productive authors in artificial intelligence research in india during 2007-16

Author	Affiliation	TP	TC	CPP	HI	ICP	%ICP	RCI
S. Das	Jadavpur University	36	365	10.14	9	23	63.89	3.67
B.K. Panigrahi	IIT-Delhi	32	340	10.63	9	13	40.63	3.85
A. Singh	University of Hyderabad	27	476	17.63	9	2	7.41	6.39
M. Nasipuri	Jadavpur University	26	58	2.23	4	2	7.69	0.81
S. Bandyopadhyay	Jadavpur University	25	59	2.36	5	14	56.00	0.86
V.K. Panchal	Defence Terrain Research Laboratory, Delhi	25	48	1.92	4	2	8.00	0.70
G.S. Tomar	Machine Intelligence Research Laboratory, Gwalior	24	74	3.08	5	4	16.67	1.12
A. Konar	Jadavpur University	23	80	3.48	4	12	52.17	1.26
R. Malhotra	Delhi Technological University	23	47	2.04	3	3	13.04	0.74
U. Maulik	Jadavpur University	23	290	12.61	7	13	56.52	4.57
	Total of 10 authors	264	1837	6.96	5.9	88	33.33	2.52
	Total of India	9730	26834	2.76				
	Share of top 10 authors in Indian total output	2.71	6.85					

4.4 Profile of Top 10 Most Productive Organizations from India

A scientometric analysis of top 10 most productive organizations from India in artificial intelligence revealed that their productivity varied from 120 to 294 publications; together they accounted for 19.31 % (1879) national publications share and 29.78 % (7992) national citations share during 2007-16. Their scientometric profile is presented in Table 5.

- Four organizations registered productivity rate above the group average of 198.9: Anna University, Chennai (294 papers), Jadavpur University, Kolkata (270 papers), IIT-Delhi (206 papers) and IIT-Kharagpur (206 papers)
- Six organizations registered citation impact and relative citation index above the group average of 4.25 citations per publication and 1.54: IIT-Delhi (7.33 and 2.66), ISI-Kolkata (6.12 and 2.22), IIT-Bombay (5.3 and 1.92), IIT-Kharagpur (4.89 and 1.77), Jadavpur University, Kolkata (4.56 and 1.65) and IISc-Bangalore (4.42 and 1.6)
- Seven organizations registered international collaborative papers above the group average of 17.26 %: Jadavpur University, Kolkata (29.63 %), IIT-Madras (27.61 %), ISI-Kolkata (26.55 %), IISc-Bangalore (24.68 %), IIT-Bombay (22.5 %), IIT-Delhi (18.93 %), and IIT-Kharagpur (18.23 %).

4.5 Profile of Top 10 Most Productive Indian Authors

A scientometric analysis of top 10 most productive authors from India in artificial intelligence revealed that their productivity varied from 23 to 36 publications. Together they contributed 2.71 % (264) share to national publications output

Table 7. Top 15 most productive journals in artificial research in India during 2007-16

Journals	Number of Papers		
	2007-11	2012-16	2007-16
Applied Soft Computing Journal	10	32	42
Expert Systems & Applications	12	28	40
Neural Computing & Applications	0	30	30
International Journal of Applied Engineering Research	0	24	24
Journal of Intelligent and Fuzzy Systems	2	21	23
Information Sciences	3	19	22
Soft Computing	2	18	20
International Journal of Electric Power & Energy Systems	3	16	19
Journal of Machine Learning Research	0	18	18
International Journal of Advanced Manufacturing Technology	8	9	17
Total of 10 journals	40	215	255
Total India journal output	435	1215	1650
Share of top 10 journals in Indian journal output	9.20	17.70	15.45

Table 8. Significant keywords in literature on artificial intelligence research in India during 2007-16

Keyword	Frequency
Artificial intelligence	9496
Algorithms	1792
Learning systems	1687
Data mining	1060
Optimization	937
Learning algorithms	719
Neural networks	667
Machine learning	596
Genetic algorithms	536
Evolutionary algorithms	458
Forecasting	454
Particle swam optimization	444
Ant colony optimization	439
Decision support systems	430
Computational theory	388
Image processing	386
Clustering algorithms	365
Pattern recognition	363
Swarm intelligence	360
Fuzzy logic	354
Telecommunication networks	324

and 6.85 % (1837) share to national citations output during 2007-16. Their scientometric profile is presented in Table 6.

- Three authors registered productivity rate above the group average of 26.4: S. Das (36 papers), B.K.Panigrahi (32 papers) and A. Singh (27 papers)
- Four authors registered citation impact and relative citation index above the group average of 6.96 citations per publication and 2.52: A. Singh (17.63 and 6.39), U. Maulik (12.61 and 4.57), B.K. Panigrahi (10.63 and 3.85) and S. Das (10.14 and 3.67)
- Five authors registered international collaborative papers above the group average of 33.33 %: S. Das (63.89 %), U. Maulik (56.52 %), S. Bandyopadhyay (56.0 %), A. Konar (52.17 %) and B.K. Panigrahi (40.63 %).

4.6 Medium of Research Communication

Of the total publications output by India in artificial intelligence research, 61.73 % (6,006) appeared as conference papers, 21.17 % (2,060) in book series, 16.96 % (1,650) in journals, and the rest as books (10) and trade publications (4). The top 10 journals accounted for 15.45 % share (255 papers) of total country output appearing in journal medium during 2007-16. The publication output in these 15 journals varied between 17 and 42 papers per journal; five-year output by India in these 15 journals increased marginally from 9.20 % in 2007-11 to 17.70 % in 2012-16. The top most productive journal (with 42 papers) was *Applied Soft Computing Journal*, followed by *Expert Systems & Applications* (40 papers), *Neural Computing*

& Applications (30 papers), *International Journal of Applied Engineering Research* (24 papers), etc. during 2007-16 as shown in Table 7.

4.7 Significant Keywords

Around 30 significant keywords have been identified from the literature, which seek to highlight possible trends in artificial intelligence research. These keywords are listed in Table 8 in the decreasing order of the frequency of their occurrence in the literature covering period 2007-16.

4.7 Highly Cited Papers

A total of 24 paper received 100 and above citations per paper during 2007-16 and were accordingly identified as highly cited paper. Together these 24 papers cumulated 3899 citations during 2007-16, with an average of 162.46 citations per paper. Their citation spread ranged between 104 and 426 citations per paper.

Of the 24 highly cited paper, 11 resulted from stand alone single organizations (publishing only non-collaborative research papers) and 13 from two or more organisations participating as a group in collaborative research (published 4 national collaborative papers and 9 international collaborative papers). Among international collaborative papers, the largest participation was from USA and U.K. (4 paper each), followed by Germany, Singapore and Germany (2 papers each), Japan, Mexico, Australia, Qatar, Canada, Italy and Poland (1 paper each). The 24 highly cited papers involved the participation of 109 author from 70 organisation (28 Indian).

- Among the Indian organizations involved in research, Microsoft Research India, Bangalore contributed 3 papers, 2 papers by Indian Statistical Institute, Kolkata, and 1 paper each by IIT-Delhi, IIT-Bombay, IIT-Kanpur, IIT-Roorkee, Indian Institute of Science, Bangalore, Central Electronics Research Institute, Pilani, Institute of Microbial technology, Chandigarh, National Institute of Oceanography, Goa, Anna University, Anna University of Technology, Madurai, Bharathidasan University, Jadavpur University, Periyar Maniammai University, Tanjore, University of Hyderabad, University of Kalyani , Birla Institute of Technology & Science, Pilani, Cambridge Institute of Technology, Ranchi, Institute of Technology, BHU, Varanasi, Motilal National Institute of Technology, Allahabad, National Institute of Technology, Kurukshetra, National Institut of Technology, Tiruchirappalli, Punjab Engineering College, Chandigarh, Manipal DOT Net, General Motors India, Bangalore, IBM Research, Bangalore and Institute of Medical Sciences, BHU, Varanasi.

- Of the 24 highly cited paper, 16 were published as article, 5 as review paper and 3 as conference paper. These 24 highly cited papers were published in 15 journals, of which 3 paper were published in *IEEE Transactions on Pattern Analysis and Machine Intelligence* (IF=7.34) and *Expert Systems and Applications* (IF=4.68), 2 papers in *Applied Soft Computing Journal* (IF=2.857) and *Bioinformatics* (IF = 5.766) and 1 paper each in *IEEE Transactions on Image Processing* (IF=4.70), *IEEE Transactions on Medical Imaging* (IF-3.39), *IEEE Transactions on Power Systems* (IF = 2.814), *International Journal of Electric Power & Energy Systems* (IF-3.289), *Journal of Medical Physics* (IF=0.98), *Journal of Theoretical Biology* (IF=2.21), *Neural Computing & Applications* (IF=1.492), *PLOS One* (IF=3.54), *Proteins: Structure, Functions & Genetics* (IF=2.499), *Renewable Energy* (IF=4.357) and *Renewable & Sustainable Energy Development* (IF=1.18).

5. SUMMARY AND CONCLUSION

Using publications data from Scopus database, this study provides a quantitative and qualitative description of artificial intelligence research covering a period of 10 years. The global R&D efforts in artificial intelligence are now spread across 100+ countries; the total world output cumulated to 152655 publications during 2007-16. Top 10 countries in the world accounted for 74.32 per cent global publication share in artificial intelligence research; country wise their global share ranged between 3.68 per cent and 19.46 per cent, with China accounting for the largest global publications share (19.46 %), followed by USA (17.96 %), India (6.37 %), U.K. (6.33 %), etc.

India's growth rate in artificial intelligence research was 27.45 per cent compared to 9.82 per cent by the world. In the world ranking, India ranks third highest with 6.37 per cent global publications share (a total of 9730 publication in 10 years). Its research impact averaged to mere 2.76 citations per paper. India's share of international collaborative publications was mere 10.34 per cent. India's top 10 organisations accounted for 19.31 per cent national publications share and 29.78 per cent national citation share during 2007-16. Computer Science, among subjects, contributed the largest publication share (86.99 %), followed by engineering (30.69 %), mathematics (15.95 %), and several other disciplines during 2007-16. Of the 9730 publication contributed by India in artificial intelligence research, only 24 emerged as highly cited publications, averaging 162.46 citations per paper. These 24 highly cited papers were the outcome of participation by 109 authors from 70 organizations, and published in 15 journals. Of the 24 highly cited papers, only 9 were international collaborative papers - 4 each from collaboration with the USA and U.K., 2 each from Germany, Singapore and Germany, and 1 each from Japan, Mexico, Australia, Qatar, Canada, Italy and Poland.

Conclusion: India stands third highest in the world ranking in artificial intelligence research, behind China and the USA, (among 100 + countries) with 6.37 per cent its global publications share. China and the USA dominate the world; their combined global publications share, 37.42 per cent, being the largest in artificial intelligence research. Currently, top 10 academic organizations from India account for 19.21 per cent national publications share. If India is to become competitive with the world leaders in artificial intelligence research, academic and research organizations in the country will have to give still better performance in future. To meet such expectations, the stakeholders need to play a catalytic role to build and strengthen research capacity in the nation by way of quality research environment, adequate funding, research incentives, and quality research faculty. This study

finds that India's qualitative performance has not been as stunning as its quantitative performance in research-its research impact in artificial intelligence research has been low, mere 2.76 citations per paper in 10 years; its output of highly cited papers has also been low, mere 0.25 per cent share of its total output. Hence, it is important that stakeholders pay special attention to academic and research organizations in the country encouraging them to undertake more and more new research projects, programmes in collaboration with international hubs in artificial intelligence research.

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